

Causal Branching and Singularity Replacement

A Journal-Style Speculative Framework for Black-Hole Interior Branch Formation

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Abstract

This paper presents a speculative theoretical framework in which black-hole formation does not terminate in a physical singularity. Instead, when gravitational-temporal compression drives local spacetime-flow to the causal limit c and slightly beyond, the parent branch ceases to remain a complete global description and a new causally separate child branch is formed. Within each branch, local physics remains ordinary in the intended sense: the local speed limit remains c , general-relativistic law remains valid up to the threshold, and physical content is preserved rather than destroyed. The event horizon is therefore reinterpreted not merely as a trapping surface, but as a permanent branch boundary. The child branch is born at its own intrinsic horizon scale and subsequently grows with accumulated preserved inflow. The paper develops the framework in formal terms through a threshold condition, a branch-transfer map, a local observer continuity rule, a candidate dynamic interior metric package, and a recursive branch hierarchy. It further argues that apparent beginnings, endpoints, and scale infinities may in some cases reflect descriptive exhaustion rather than literal physical divergence. This manuscript is offered as a speculative preprint intended for conceptual and mathematical evaluation on its own stated terms and is not presented as a peer-reviewed result.

Statement of Scope

The present manuscript is intentionally framed as a formal speculative theory paper. It does not claim observational confirmation, nor does it claim derivation from standard black-hole interior models. Its goal is narrower and clearer: to define the author's postulates precisely enough that their internal logic, mathematical structure, and immediate consequences can be evaluated on their own terms.

1. Introduction

The central proposal is that a black hole does not end in a terminal singularity. Rather, singularity language is treated as the false continuation of a parent-branch description beyond the point at which that description ceases to be globally valid.

The operative idea may be summarized as same physics, different geometry. Local law is not abandoned. What changes is the global causal continuation: once local spacetime-flow reaches the causal limit c , the theory posits permanent causal separation and child-branch formation.

This framing deliberately begins where the author judges standard singularity treatment to become conceptually incomplete. The present paper therefore offers a replacement scaffold rather than a modification of familiar black-hole endpoint language.

2. Foundational Definitions and Notation

Let the parent branch be denoted by M_n with metric $g^{(n)}_{(\mu\nu)}$. Let x^μ denote parent-branch coordinates, and let $R(r,t)$ denote physical metric distance from radius r to the local collapse center at external branch time t .

Define a spacetime-flow field $v_s(r,t)$ by

$$v_s(r,t) := - dR(r,t) / dt$$

where v_s is not the speed of matter through space, but the local rate at which compressive metric flow drives physical distance inward. For a simple illustrative collapse profile one may write

$$R(r,t) = r - \alpha(r) t, \quad \text{so that} \quad v_s(r,t) = \alpha(r).$$

A monotone profile compatible with the intended picture is

$$\alpha(r) = \alpha_0 \exp(-r / r_0), \quad \text{with } \alpha(0) = \alpha_{\max} \text{ and } \alpha(r) > \alpha(r_0).$$

These expressions are not presented as a unique derivation. They serve as minimal analytic scaffolding for the threshold rule introduced next.

3. Threshold Condition and Event-Horizon Reinterpretation

The threshold surface is defined by

$$\Sigma_n := \{ x^\mu \text{ in } M_n : v_s(x^\mu) = c \}.$$

In this framework, Σ_n is identified with the event horizon, but with stronger meaning than in standard trapping-surface language. It is the permanent causal boundary between the parent branch and the child branch.

The regime structure is therefore

$$\begin{aligned} v_s < c & \rightarrow \text{ordinary parent-branch regime} \\ v_s = c & \rightarrow \text{causal decoupling threshold} \\ v_s > c & \rightarrow \text{child-branch nucleation regime.} \end{aligned}$$

The framework requires only a physically realized threshold crossing. Prolonged supercritical behavior is not necessary. Even a very brief realized excursion beyond c is sufficient to initiate branch formation.

4. Branch Nucleation and Intrinsic Birth Scale

Let p_* denote the first threshold point or threshold region realized in the collapse. If there exists any neighborhood $U \subset M_n$ and any nonzero interval $\Delta t > 0$ such that $v_s(x^\mu) \geq c$ on U for Δt , then a child branch $M_{(n+1)}$ is nucleated.

Symbolically:

$$\text{Exists } U \subset M_n \text{ and } \Delta t > 0 \text{ such that } v_s(x^\mu) \geq c \text{ on } U \text{ for } \Delta t \Rightarrow M_{(n+1)} \text{ forms.}$$

The child branch is born at the size of the event horizon created there:

$$R_{\text{birth}} = R_H.$$

This birth scale is intrinsic to the child branch. It is not a size measured relative to the parent branch. A microscopic threshold event therefore yields a microscopic birth scale, while a supermassive threshold event yields a correspondingly larger intrinsic birth scale.

5. Mirror-Branch Postulate

Each child branch is mirror-like in the sense intended by the author. It is a lawful 4D spacetime domain with the same local speed limit c and the same locally valid gravitational rules as the parent branch. It is not a static exotic remnant and not a mere coordinate trick.

Formally, each branch is taken to satisfy the same local Einstein-type relation within its own causal domain:

$$\begin{aligned} G^{(n)}_{(\mu \nu)} &= 8 \pi G T^{(n)}_{(\mu \nu)}, \\ G^{(n+1)}_{(\mu \nu)} &= 8 \pi G T^{(n+1)}_{(\mu \nu)}. \end{aligned}$$

The proposal is therefore not that local physics changes after branch birth, but that the parent branch is no longer the correct global manifold for describing the continued interior state.

6. Preservation Principle and Branch-Transfer Map

The theory asserts preservation rather than destruction at the threshold. Matter, energy, charge, information, wavelength structure, force structure, and spacetime content are transferred into the child branch rather than annihilated.

Let C denote the total preserved content set. Then the transfer map Φ_n acts across the threshold as

$$\Phi_n : \Sigma_n^- \rightarrow \Sigma_{(n+1)}^+$$

with

$$\Phi_n(C_{\text{parent}}) = C_{\text{child}}.$$

For each conserved quantity Q one therefore writes

$$Q_{\text{parent},\text{out}} = Q_{\text{child},\text{in}}.$$

Representative special cases are

$$I_{\text{parent}} = I_{\text{child}}, \quad q_{\text{parent}} = q_{\text{child}}, \quad E_{\text{parent}} = E_{\text{child}}.$$

This principle is the formal replacement for singularity language that would otherwise imply undefined destruction, terminal loss, or discontinuous physical erasure.

7. Local Observer Continuity

The author's intended interpretation includes a strong continuity requirement: a traveler crossing the threshold experiences no abrupt local tearing, explosive discontinuity, or immediate physical contradiction. The boundary is globally a causal split, but locally a continuous transfer.

This is expressed by continuity of the proper interval at crossing:

$$\begin{aligned} d\tau^2 &= -g_{(\mu \nu)} dx^\mu dx^\nu, \\ d\tau_{\text{parent}} &= d\tau_{\text{child}} \quad \text{at threshold.} \end{aligned}$$

Likewise the traveler's timelike normalization remains ordinary on both sides:

$$u^\mu u_\mu = -c^2.$$

If a proportional scale-redefinition factor a_Φ acts at transfer, then local rulers and the metric scale together:

$$L' = a_\Phi L, \quad g'_{(\mu \nu)} = a_\Phi^2 g_{(\mu \nu)}.$$

Because the measuring system and the measured physical structure scale together, the traveler notices no local rupture in the transition.

8. Candidate Dynamic Interior Metric Package

The theory does not require a static regular core. The child branch is instead intended to behave as an ordinary 4D spacetime-like domain that begins at its intrinsic birth scale and then expands in all directions as preserved content enters.

A minimal working metric class consistent with that picture is

$$ds^2_{(n+1)} = - d\tau^2 + a^2(\tau, J_{in}) h_{ij} dx^i dx^j,$$

where h_{ij} is a regular spatial 3-geometry and $a(0) = R_{birth}$ in appropriate normalized coordinates.

For the most economical paper-level ansatz, one may choose h_{ij} to be spatially flat, giving a dynamic FLRW-like seed metric:

$$ds^2_{(n+1)} = - d\tau^2 + a^2(\tau, J_{in}) [d\rho^2 + \rho^2 d\Omega^2].$$

This should be understood as a candidate working ansatz, not as the unique final geometry of the theory. Its role is to capture the intended qualitative facts: local lawfulness, ordinary 4D feel, intrinsic birth scale, and all-direction expansion with accumulated inflow.

9. Growth Law and Age Dependence

Once formed, the child branch does not remain fixed at birth scale. It grows as additional preserved content enters. Its total spacetime extent therefore depends on branch age and cumulative inflow.

Let J_M denote mass-energy influx and J_I denote information influx through the branch boundary. Then

$$M_{(n+1)}(\tau) = \int_0^\tau J_M(\tau') d\tau',$$

$$I_{(n+1)}(\tau) = \int_0^\tau J_I(\tau') d\tau'.$$

A simple effective growth package may be written in flux form:

$$dC / d\tau = \int (\Sigma(\tau)) J_{in} \cdot dA,$$

$$dV_{(n+1)} / d\tau = \kappa \int (\Sigma(\tau)) J_{in} \cdot dA,$$

where C is total preserved content, $V_{(n+1)}$ is effective branch volume, J_{in} is preserved-content flux density across the branch boundary, and κ converts inflow into volumetric growth. For a roughly spherical effective branch, $V = (4/3) \pi R^3$ and $\Phi_{in} = 4 \pi R^2 J_{bar}$, giving $dR / d\tau = \kappa J_{bar}$ in the simplest averaged case.

This continuous-inflow law is the baseline case. If a separate branch later merges with $M_{(n+1)}$, the balance law generalizes by adding discrete merger contributions at merger times τ_k :

$$dC / d\tau = \int (\Sigma(\tau)) J_{in} \cdot dA + \sum_k \Delta C_k \delta(\tau - \tau_k),$$

$$dV_{(n+1)} / d\tau = \kappa \int (\Sigma(\tau)) J_{in} \cdot dA + \sum_k \Delta V_k \delta(\tau - \tau_k).$$

Accordingly, branch growth need not be sourced only by smooth isotropic inflow. The framework also permits later branch-branch merger events as distinct additions of preserved content and spacetime extent. This does not reverse the one-way parent-to-child transfer rule; it supplements the baseline growth law with optional discrete merger terms.

with F and G monotone increasing. On this picture, the child branch may initially contain only a limited lawful region — for example a small stellar or solar-system-scale domain — and then expand in all directions as further content enters.

10. Singularity Replacement Rule

In the present framework, a singularity is not treated as the final physical state. Instead, before parent-branch quantities are taken to their would-be terminal divergence, the causal threshold is reached and the continuation transfers to a new branch.

Thus one does not take

$$\lim K(x^\mu) \rightarrow \text{infinity}$$

as the final physical continuation in M_n . Rather, the correct continuation is

$$\begin{aligned} v_s = c & \Rightarrow \text{parent-branch global validity ends,} \\ v_s > c & \Rightarrow \text{continuation proceeds in } M_{(n+1)}. \end{aligned}$$

The proposal therefore replaces terminal singularity language with branch formation at threshold. It does not regularize a singularity after the fact; it avoids singularity as the final continuation altogether.

11. One-Way and Permanent Separation

The branch boundary is one-way and permanent. Once content has crossed into the child branch, it does not causally return to the parent branch through the same boundary. Inside remains inside; outside remains outside.

Formally one writes

$$\begin{aligned} M_n \cap M_{(n+1)} &= \Sigma_n, \\ \Sigma_n(t \geq t_*) &\text{ is permanent,} \\ \Phi_n^{(-1)} &\text{ is not a physically traversable return channel.} \end{aligned}$$

If a future observer in the child branch were somehow to drive local spacetime-flow beyond c again, that event would not reopen the parent branch. It would generate yet another child branch from within the existing one.

12. Recursive Branch Hierarchy

Every branch may contain black holes, and every black hole may in turn generate further child branches by the same threshold rule. The total structure is therefore recursively generative.

Symbolically:

$$M_n \rightarrow \{ M_{(n+1)}^{(1)}, M_{(n+1)}^{(2)}, \dots \}.$$

Distinct daughter branches are generically separate after formation, but the framework does not forbid later branch-branch merger events if a new lawful interface forms between previously separate domains.

The default postulate is therefore separation after birth, not eternal non-interaction. Parent-child return across the original boundary remains forbidden, while later merger is treated as a distinct process rather than reversal of branch transfer.

On this view, our own universe may itself be one branch within a wider hierarchy rather than a unique top-level spacetime.

13. Immediate Consequences of the Framework

Several direct consequences follow from the postulates above.

First, there is no true terminal singularity. The point where singularity language would normally be invoked is instead the point at which parent-branch continuation becomes physically incomplete.

Second, there is no true shrinking by destruction of physical content. If content is preserved through branch transfer, then the black hole is not a terminal dissipative endpoint in the sense of physical annihilation.

Third, the framework does not require extra external hair beyond the ordinary macroscopic horizon-defined properties of the branch-forming object. Additional external structure is not needed in order to preserve content, because preservation is accomplished by branch transfer rather than by storing hidden complexity in extra exterior observables.

Fourth, every black hole becomes a potential branch-birth event, yielding a recursive cosmological picture.

These are theory consequences rather than established observations. Their function here is to show what the framework commits itself to if its postulates are accepted.

14. Foundational Implications

The present framework also carries broader philosophical and structural implications beyond the immediate black-hole replacement rule. Its central suggestion is that apparent beginnings, endings, and scale infinities may sometimes arise from descriptive overextension rather than from physically realized terminal objects.

In this framework, the search for an absolute beginning and the search for an absolute endpoint may reflect the same descriptive limitation: the attempt to impose a single bounded causal narrative on a recursively generative reality. If black holes continually produce further branches, then the expectation that reality must terminate in a final center, first point, or last endpoint becomes less compelling than in one-branch cosmologies.

Likewise, notions such as infinitely small or infinitely large may become pathological only when scale is interpreted outside the domain of a lawful branch description. A scale is not problematic merely because it is extreme. It becomes problematic when a coordinate description is forced past the causal domain in which its concepts remain physically meaningful.

On this view, apparent infinities do not necessarily indicate physical divergence. They may instead indicate the exhaustion of a chosen descriptive framework. The singularity is then reinterpreted not as a literal terminal object, but as a marker that a parent-branch description has reached the edge of its valid continuation.

A related caution applies to cosmological expansion language. The concern is not that a constant dark-energy model would simply recreate a singularity in reverse. Rather, the concern is methodological: uncritically accepting infinite metric extension may repeat the same descriptive habit found in singularity reasoning, namely allowing a mathematical limit process to stand in for a completed physical explanation. On this reading, infinite compression and infinite extension may be opposite-looking versions of the same explanatory failure. The present framework is motivated in part by the view that both may signal exhaustion of a chosen description rather than completion of the underlying physical story.

This implication aligns with the paper's treatment of observational ambiguity. A repeating process and a globally self-related causal structure can appear identical from limited observational access. In the same way, a framework that presumes a single linear temporal chain may mistake a more complex recursive structure for a beginning, an end, or an infinite breakdown simply because its ontology is too narrow.

A recursively branching ontology therefore offers a natural way to preserve continuity, conservation, and local lawful physics without requiring terminal singularities, absolute centers, or final scale cutoffs. The claim here is not that the present paper proves an actual completed infinity of branches. Rather, it argues that recursive branch generation makes infinity conceptually less pathological and removes the need to treat descriptive dead ends as physical necessities.

15. Limits and Open Refinements

The present draft now specifies more than a purely qualitative idea: it states a threshold rule, a transfer map, a continuity condition, a candidate dynamic interior metric package, a growth law based on accumulated inflow, explicit consequences of the framework, and a broader foundational interpretation of how apparent infinities may arise.

Even so, several natural refinements remain open. First, the theory has not yet selected one unique final interior metric; the FLRW-like seed remains a candidate working ansatz rather than a unique solution. Second, the exact functional form of branch growth, including the detailed dependence of boundary area, inflow flux, and merger events, remains to be specified. Third, the framework still lacks a conventional observational discriminator distinct from mainstream black-hole interior proposals.

A further caution concerns cosmological analogy. The present framework does not identify branch growth with standard dark energy, nor does it claim that observed cosmic acceleration has already been explained by the theory. It permits only a limited conceptual analogy: an observer confined to a branch could infer an internal large-scale expansion driver if unaware that spacetime extent and preserved content were being added through processes outside that observer's accessible domain. In that restricted sense, branch growth may provide an observational analogue to some features attributed to dark energy. By contrast, branch-merger events would more naturally introduce directional or anisotropic effects, and are therefore not treated here as the primary analogue of smooth near-isotropic large-scale cosmic acceleration.

These limitations do not prevent evaluation of the theory's core logic. They identify the next steps required if one wishes to push the framework from a coherent speculative scaffold toward a more fully parameterized mathematical model.

16. Conclusion

This paper has reformulated the author's proposal in a more professional, journal-style form. The central claim remains straightforward: black holes do not terminate in physical singularities, but in causal branch formation triggered when local spacetime-flow reaches and slightly exceeds the causal limit c .

Within each branch, local physics remains ordinary in the intended sense. The event horizon is reinterpreted as a permanent branch boundary, physical content is preserved rather than destroyed, the child branch is born at its own intrinsic horizon scale, and subsequent growth depends on accumulated inflow over branch time.

Taken together, these postulates yield a coherent speculative alternative to terminal singularity language and motivate a recursive hierarchical picture of black-hole-driven branch formation. In the present version, branch growth is modeled both by continuous preserved inflow across a growing boundary and, optionally, by later branch-branch merger events treated as discrete additions rather than reversals of one-way threshold transfer.

Appendix A. Core Postulates at a Glance

Postulate	Formal statement
Threshold	$\Sigma_n = \{ x^\mu \text{ in } M_n : v_s(x^\mu) = c \}$
Nucleation	Any realized $v_s > c$ excursion produces child-branch formation.

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Preservation	$\Phi_n(C_{\text{parent}}) = C_{\text{child}}$
Observer continuity	$d\tau_{\text{parent}} = d\tau_{\text{child}}$ and $u^\mu u_\mu = -c^2$
Intrinsic birth scale	$R_{\text{birth}} = R_H$
Growth	$V_{(n+1)}(\tau) = F(M_{(n+1)}(\tau))$, with F monotone increasing
Permanence	Σ_n remains permanent once formed.
One-way rule	Φ_n^{-1} is not a traversable return channel.
Recursion	Any branch may generate further child branches by the same threshold rule.